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Unconfined compressive strength prediction of stabilized expansive clay soil using machine learning techniques
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Abstract
This paper evaluates the potential of machine learning techniques, namely, Gaussian Process Regression (GPR) and Support Vector Machine (SVM), for the prediction of unconfined compressive strength (UCS) of expansive clay soil treated with hydrated-lime-activated rice husk ash. A laboratory dataset containing 121 records has been used with input parameters, including hydrated-lime-activated rice husk ash, liquid limit, plastic limit, plastic index, optimum moisture content, clay activity, and maximum dry density. The performances of the GPR and SVM models are assessed using statistical metrics, including the coefficient of determination (R2), mean absolute error (MAE), root-mean-square error (RMSE), relative root-mean-square error (RRMSE), and performance indicator (ρ). The analysis of the R2 together with MAE, RMSE, RRMSE, and ρ values for the UCS demonstrates that the SVM and GPR models achieved better prediction results, i.e., R2=0.9998,MAE=0.0514,RMSE= 0.1408, and ρ = 0.0004 and R2=0.9998,MAE=0.3430, RMSE= 0.4455, and ρ = 0.0011, respectively, as compared to the artificial neural network model recently developed in the literature with (R2 = 0.9900, MAE = 0.3500, RMSE = 4.9300, RRMSE = 0.2000, and ρ = 0.1000) in test phase, which indicates that both models are efficient and reliable for practical applications. Furthermore, the sensitivity analysis result shows that maximum dry density was the key parameter affecting the UCS. © The Author(s), under exclusive licence to Springer Nature Switzerland AG 2023.

Author Keywords
Expansive soil; Gaussian process regression; Support vector machine; Unconfined compressive strength

Index Keywords
Clay, Compressive strength, Errors, Forecasting, Gaussian distribution, Gaussian noise (electronic), Hydration, Learning algorithms, Learning systems, Lime, Mean square error, Neural networks, Sensitivity analysis; Clay soil, Expansive clays, Expansive soils, Gaussian process regression, Machine learning techniques, Mean absolute error, Regression vectors, Root mean square errors, Support vectors machine, Unconfined compressive strength; Support vector machines

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References

- Abdi, Y., Momeni, E., Khabir, R.R.
  A reliable PSO-based ANN approach for predicting unconfined compressive strength of sandstones
  (2020) *Open Constr Build Technol J*, 14 (1), pp. 237-249.
- Ahmad, M.
  Evaluating seismic soil liquefaction potential using bayesian belief network and C4. 5 decision tree approaches
  (2019) *Appl Sci*, 9 (20), p. 4226.
- Ahmad, M., Tang, X., Ahmad, F.
  Evaluation of liquefaction-induced settlement using random forest and REP tree models: taking pohang earthquake as a case of illustration, in natural hazards-

impacts, adjustments & resilience
(2020) *IntechOpen*,

- Ahmad, M.
A hybrid approach for evaluating CPT-based seismic soil liquefaction potential using Bayesian belief networks
(2020) *J Central South Univ*, 27 (2), pp. 500-516.
1:CAS:528:DC%2BC1MXitlKhtb3J

- Ahmad, M.
A step forward towards a comprehensive framework for assessing liquefaction land damage vulnerability: exploration from historical data
(2020) *Front Struct Civ Eng*, 14 (6), pp. 1476-1491.

- Ahmad, M.
Predicting the pillar stability of underground mines with random trees and C4. 5 decision trees
(2020) *Appl Sci*, 10 (18), p. 6486.
1:CAS:528:DC%2BB3cXitFakurjI

- Ahmad, M., Xiao-Wei, T., Qiu, J.-N., Ahmad, F.
Evaluation of liquefaction-induced lateral displacement using Bayesian belief networks
(2021) *Front Struct Civil Eng*,

- Ahmad, M.H.
Supervised learning methods for modeling concrete compressive strength prediction at high temperature
(2021) *Materials*,
35009436, 8746208

- Ahmad, M.
Application of machine learning algorithms for the evaluation of seismic soil liquefaction potential
(2021) *Front Struct Civ Eng*, 15 (2), pp. 490-505.

- Ahmad, M.
Development of prediction models for shear strength of rockfill material using machine learning techniques
(2021) *Appl Sci*, 11 (13), p. 6167.
1:CAS:528:DC%2BB3MXit1GqsLnL

- Ahmad, M.
Rockburst hazard prediction in underground projects using two intelligent classification techniques: a comparative study
(2021) *Symmetry*, 13 (4), p. 632.
2021Symm..13.632A

- Ahmad, M.
Prediction of ultimate bearing capacity of shallow foundations on cohesionless soils: a Gaussian process regression approach
(2021) *Appl Sci*, 11 (21), p. 10317.
1:CAS:528:DC%2BB3MXisVygtLvO

- Ahmad, M.
Predicting subgrade resistance value of hydrated lime-activated rice husk ash-treated expansive soil: a comparison between M5P, support vector machine, and gaussian process regression algorithms
(2022) *Mathematics*, 10 (19), p. 3432.
4434345

- Armaghani, D.J., Asteris, P.G.
  A comparative study of ANN and ANFIS models for the prediction of cement-based mortar materials compressive strength
  (2021) *Neural Comput Appl*, 33 (9), pp. 4501-4532.

- Asteris, P.G.
  Prediction of cement-based mortars compressive strength using machine learning techniques
  (2021) *Neural Comput Appl*, 33 (19), pp. 13089-13121.

- Asteris, P.G.
  Soft computing techniques for the prediction of concrete compressive strength using Non-Destructive tests
  (2021) *Constr Build Mater*, 303.

- Asteris, P.G.
  Evaluation of the ultimate eccentric load of rectangular CFSTs using advanced neural network modeling
  (2021) *Eng Struct*, 248.

- Asteris, P.G.
  Surrogate models for the compressive strength mapping of cement mortar materials
  (2021) *Soft Comput*, 25 (8), pp. 6347-6372.

- Asteris, P.G.
  Soft computing-based estimation of ultimate axial load of rectangular concrete-filled steel tubes
  (2021) *Steel Compos Struct*, 39 (4), pp. 471-491.

- Asteris, P.G.
  Soft computing-based models for the prediction of masonry compressive strength
  (2021) *Eng Struct*, 248.

- Cheng, Y.M.
  Particle swarm optimization algorithm for the location of the critical non-circular failure surface in two-dimensional slope stability analysis
  (2007) *Comput Geotech*, 34 (2), pp. 92-103.

- Chou, J.-S.
  Optimizing the prediction accuracy of concrete compressive strength based on a comparison of data-mining techniques
  (2011) *J Comput Civ Eng*, 25 (3), pp. 242-253.

- Das, S.K., Samui, P., Sabat, A.K.
  Application of artificial intelligence to maximum dry density and unconfined compressive strength of cement stabilized soil
  (2011) *Geotech Geol Eng*, 29 (3), pp. 329-342.

- Ercanoglu, M., Gokceoglu, C.
  Assessment of landslide susceptibility for a landslide-prone area (north of Yenice, NW Turkey) by fuzzy approach
  (2002) *Environ Geol*, 41 (6), pp. 720-730.

- Fattahi, H.
  Prediction of slope stability using adaptive neuro-fuzzy inference system based on clustering methods
  (2017) *J Min Environ*, 8 (2), pp. 163-177.
  3695815

- Fowler, B.
  A sociological analysis of the satanic verses affair
  (2000) *Theory Cult Soc*, 17 (1), pp. 39-61.

- Gandomi, A.H., Roke, D.A.
  Assessment of artificial neural network and genetic programming as predictive tools
  (2015) *Adv Eng Softw*, 88, pp. 63-72.

- Gao, W.
  Stability analysis of rock slope based on an abstraction ant colony clustering algorithm
  (2015) *Environ Earth Sci*, 73 (12), pp. 7969-7982.
  2015EES..73.7969G

- Güllü, H.
  Function finding via genetic expression programming for strength and elastic properties of clay treated with bottom ash
  (2014) *Eng Appl Artif Intell*, 35, pp. 143-157.

- Hoang, N.-D., Pham, A.-D.
  Hybrid artificial intelligence approach based on metaheuristic and machine learning for slope stability assessment: a multinational data analysis
  (2016) *Expert Syst Appl*, 46, pp. 60-68.

- Iqbal, M., Onyelowe, K.C., Jalal, F.E.
  Smart computing models of California bearing ratio, unconfined compressive strength, and resistance value of activated ash-modified soft clay soil with adaptive neuro-fuzzy inference system and ensemble random forest regression techniques
  (2021) *Multiscale Multidiscip Model Exp Des*, 4 (3), pp. 207-225.

- Jalal, F.E.
  Predicting the compaction characteristics of expansive soils using two genetic programming-based algorithms
  (2021) *Transp Geotech*, 30.

- Jalal, F.E.
  Predictive modeling of swell-strength of expansive soils using artificial intelligence approaches: ANN, ANFIS and GEP
  (2021) *J Environ Manag*, 289.

- Jalal, F.E.
  Fractal approach in expansive clay-based materials with special focus on compacted GMZ bentonite in nuclear waste disposal: A systematic review
  (2021) *Environ Sci Pollut Res*, 28 (32), pp. 43287-43314.
  1:CAS:528:DC%2BB3MXisFagsrjO

- Javadi, A.A., Rezania, M., Nezhad, M.M.
  Evaluation of liquefaction induced lateral displacements using genetic programming
  (2006) *Comput Geotech*, 33 (4-5), pp. 222-233.

- Kişi, Ö., Uncuoğlu, E.
  Comparison of three back-propagation training algorithms for two case studies
  (2005) *Ind J Eng Mater Sci*, 12, pp. 434-442.

- Liang, W.
  Predicting hard rock pillar stability using GBDT, XGBoost, and LightGBM algorithms
  (2020) *Mathematics*, 8 (5), p. 765.

- Ly, H.-B.
  Estimation of axial load-carrying capacity of concrete-filled steel tubes using surrogate models
  (2021) *Neural Comput Appl*, 33 (8), pp. 3437-3458.

- MolaAbasi, H., Shooshpasha, I.
  Prediction of zeolite-cement-sand unconfined compressive strength using polynomial neural network
  (2016) *Eur Phys J plus*, 131 (4), pp. 1-12.
  1:CAS:528:DC%2BC28XmtlShsbs%3D

- Momeni, E.
  Prediction of uniaxial compressive strength of rock samples using hybrid particle swarm optimization-based artificial neural networks
  (2015) *Measurement*, 60, pp. 50-63.
  2015Meas..60..50M

- Mozumder, R.A., Laskar, A.I., Hussain, M.
  Empirical approach for strength prediction of geopolymer stabilized clayey soil using support vector machines
  (2017) *Constr Build Mater*, 132, pp. 412-424.
  1:CAS:528:DC%2BC2sXntVahtLY%3D

- Onyelowe, K.C.
  Application of 3-algorithm ANN programming to predict the strength performance of hydrated-lime activated rice husk ash treated soil
  (2021) *Multiscale Multidiscip Model, Exp Des*, 4 (4), pp. 259-274.

- Pham, T.A.
  Design deep neural network architecture using a genetic algorithm for estimation of pile bearing capacity
  (2020) *PLoS ONE*, 15 (12).
  1:CAS:528:DC%2BB3cXis1yrsbjL, 33332377, 7746167

- Rasmussen, C., Williams, C.
  (2006) *Gaussian processes for machine learning*, pp. 715-719.
  Cambridge, The MIT Press

- Son, Y.-J.
  Application of support vector machine for prediction of medication adherence in heart failure patients
  (2010) *Healthcare Inf Res*, 16 (4), pp. 253-259.
  2010cmtd.book...S, 3449835

- Song, Y.
  Susceptibility assessment of earthquake-induced landslides using Bayesian network: a case study in Beichuan
  (2012) *China Comput Geosci*, 42, pp. 189-199.
  2012CG...42.189S

- Van Duc, B., Kennedy, O.
  Adsorbed complex and laboratory geotechnics of Quarry Dust (QD) stabilized lateritic soils
  (2018) *Environ Technol Innov*, 10, pp. 355-363.

- Van, D.B., Onyelowe, K.C., Van-Nguyen, M.
  Capillary rise, suction (absorption) and the strength development of HBM treated with QD base geopolymer
  (2018) *Int J Pavement Res Technol*, 11, pp. 759-765.

- *Modeling of Transport demand–analyzing, Calculating, and Forecasting Transport Demand: By VA Profillidis and GN Botzoris.*, 472, p. pp. $125.
  Elsevier, Amsterdam, paperback and ebook, eBook ISBN: 9780128115145, Paperback ISBN: 9780128115138. 2020, Taylor & Francis

- Wu, X., Kumar, V.
  (2009) *The top ten algorithms in data mining*,
  New York, CRC Press

- Zhou, J.
  Prediction of ground vibration induced by blasting operations through the use of the Bayesian Network and random forest models
  (2020) *Soil Dyn Earthq Eng*, 139.

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